

AN EVALUATION OF CONTENDER
HELMETS FOR VISUAL
OBSTRUCTION AND
PRELIMINARY VALIDATION OF A
VISUAL OBSTRUCTION
MEASURING TOOL

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Defence and Civil
INSTITUTE OF ENVIRONMENTAL MEDICINE
INSTITUT DE MEDECINE ENVIRONNEMENTALE
pour la défense

1133 Sheppard Avenue West, PO Box 2000, North York, Ontario, Canada M3M 3B9
Tel. (416) 635-2000 Fax. (416) 635-2104

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Y. Shek

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
North York, Ontario
Canada M3M 3B9

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DEPARTMENT OF NATIONAL DEFENCE – CANADA

EXECUTIVE SUMMARY

The aim of this study was to (1) use a headform-perimeter to evaluate contender army helmets for visual interference; and (2) determine the effectiveness and validity of using the headform-perimeter to measure visual interference compared to using human subjects.

A headform was made in-house to be used with a standard Goldmann perimeter. The headform-perimeter was used to evaluate the six contender helmets for visual obstructions, by measuring loss of field of view (FOV). In a separate study, human subjects FOV measurements were obtained with the same Goldmann perimeter. Subjects' loss of FOV while wearing various helmets were measured.

The results of this study showed that: (1) all brimmed helmets caused significant reductions of FOV when compared with baseline measurements (no helmet); (2) brimless helmets (British and Israeli) did not cause any significant reduction of FOV; and (3) the headform FOV data were consistent with subjects' FOV measurements, for three of the six test helmets.

It is recommended that:

- a brimless- or reduced-brim helmet be considered in any future Canadian Forces (CF) purchase;
- future helmet requisitions be evaluated for visual obstruction in a similar manner before procurement; and
- a similar test method be used in the future to define Statements of Requirement, performance specifications, and other related documents.

ABSTRACT

The aim of this study was to (1) use a headform-perimeter to evaluate contender army helmets for visual interference; and (2) determine the effectiveness and validity of using the headform-perimeter to measure visual interference compared to using human subjects. A headform was made in-house to be used with a standard Goldmann perimeter. The headform-perimeter was used to evaluate the six contender helmets for visual obstructions, by measuring loss of field of view (FOV). In a separate study, human subjects FOV measurements were obtained with the same Goldmann perimeter. Subjects' loss of FOV while wearing various helmets were measured. The results showed that: (1) all brimmed helmets caused significant reductions of FOV when compared with baseline measurements (no helmet); (2) brimless helmets (British and Israeli) did not cause any significant reduction of FOV; and (3) the headform FOV data were consistent with subjects' FOV measurements, for three of the six test helmets.

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1. INTRODUCTION

1.1 Background

As part of clothing and equipment testing and development, DCIEM has developed a method and related hardware for testing the visual interference of helmets. The measurement device, a headform-perimeter, comprises a standard Goldmann perimeter for measuring normal field of view (FOV; see Figure 1) (Haag-Streit Company, Berne, Switzerland) and an attachable headform that was made in-house (DCIEM, Canada; see Annex A).

The headform was used in order to minimize between-subject differences when comparing the items of equipment, such as helmets, that may reduce peripheral vision. The apparatus can also test the peripheral vision of human subjects, once the headform is removed. This interchangeability is important for validating the reliability and applicability of the headform-perimeter system.

The present system is similar to the European Stoll headform-perimeter¹. The DCIEM headform-perimeter and the Stoll headform-perimeter differ in visual range (the Stoll perimeter covers a larger peripheral range, up to 120° laterally) and the headform size and interpupillary distance (the Stoll headform has a smaller interpupillary distance).

1.2 Aim

To (1) use a headform-perimeter to evaluate contender army helmets for visual interference; and (2) determine the effectiveness and validity of using the headform-perimeter to measure visual interference compared to using human subjects.

1.3 Normal field of view - Definition

For each eye, the normal visual field is an irregular oval which measures approximately 60° upward, 60° inward, 70° to 75° downward, and 100° to 110° outward, when the eyes are fixated to the front. The field of the two eyes together is a combination of the right and left monocular fields. The combined fields form a rough oval extending to about 200° laterally and 130° vertically. The visual field is limited by the nose and brows².

1.4 Different methods of measuring FOV

There are a number of methods to measure FOV for human subjects². One major difference in methods is that some measure FOV while subjects' eyes are fixated to the front while others measure FOV while the subjects are encouraged to move their eyes to the most lateral extremes.

¹ See Reference 1.

Another method used to measure FOV is to replace human subjects with a headform. This method eliminates the inter-subjects error, but has a number of issues of its own. When a headform is used instead of human subjects, there is controversy as to which interpupillary distance the headform should have. To date, there is no standardized interpupillary distance(s) for headforms.

2. METHOD

2.1 *Apparatus*

Goldmann perimeter

A standard Goldmann spherical peripheral vision tester or "perimeter" was used (Figure 1 below). It was set on an adjustable table equipped for the perimeter (table not shown here).

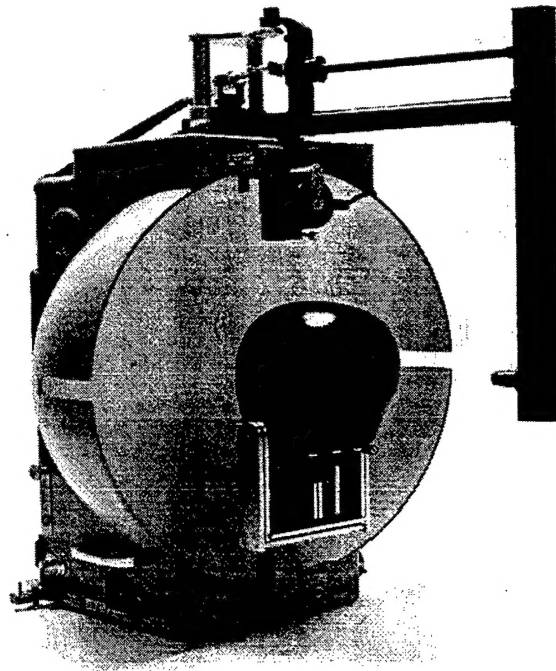


Figure 1. Headform mounted in a Goldmann perimeter.

Headform and headform mount

A headform was constructed in-house for the purposes of this study. The headform used was geometrically similar to the male Hybrid III headform (see Annex A for more details). Headform circumference was 59.2 cm (95th percentile male or 99th percentile female³). Headform breadth was 15.4 cm (40th percentile male and 90th percentile female). Headform length was 20.4 cm (70th percentile male and 99th percentile female).

A special mount was constructed for attaching the headform to the Goldmann perimeter. The mount unit replaced the chin-head support on the perimeter for subjects. The mount allowed the headform to be attached and adjusted vertically and horizontally such that the eyes of the headform were properly aligned within the Goldmann perimeter.

The eyes of the headform

Two light bulbs which approximate point sources of light were fixed inside the headform such that the centres of the filaments were at the centres of the eye positions. Visual obstructions greater than baseline measurements were shown on the illuminated perimeter screen as shadows cast by the obstruction (helmet).

The interpupillary distance of the headform "eyes" (lightbulbs) was 60 mm (10th percentile male and 35th percentile female³). The eyes were lopsided, however. The right eye was higher than the left eye by 2.5 mm. It was decided that this flaw was acceptable for the purposes of this initial study, due to the lack of standards for such headforms.

2.2 Headform experimental conditions: Helmet x Position x Eye

Helmet

Six helmets were evaluated for their amount of visual obstruction compared to each other and to baseline (no helmets). The six helmets that were evaluated for visual obstruction were the (1) Canadian M-1 in-service helmet, (2) U.S. PASGT, (3) German Schuberth-Helme, (4) Canadian prototype Barrday, (5) British Mk-6, and (6) Israeli Orlite (Figures 2a and 2b). Each helmet was tested three times in a counter-balanced order.



Figure 2a. Brimmed helmets. Top left: PASGT; top right: Schuberth-Helme; bottom left: Barrday; bottom right: M-1.



Figure 2b. Brimless helmets. Left: Mk-6; Right: Orlite.

Positions

The rotating arm of the headform-perimeter was swiveled to each of eight positions within the lateral visual field. At each of the positions, the shadow on the perimeter cast by the visual obstruction (light source from the headform light bulbs "eyes") was plotted by the experimenter.

The eight positions within the lateral visual field were the following: 37.5°, 52.5°, 67.5°, 82.5°, 97.5°, 112.5°, 127.5°, and 142.5° (see Figure 3 below). The fixation point to the front of the headform was at 90°. The position to the headform's furthest right was 37.5° and the furthest left was 142.5°. The order that the experimenter plotted the shadow cast by the obstruction at the eight lateral visual field positions was from right to left (37.5° to 142.5°).

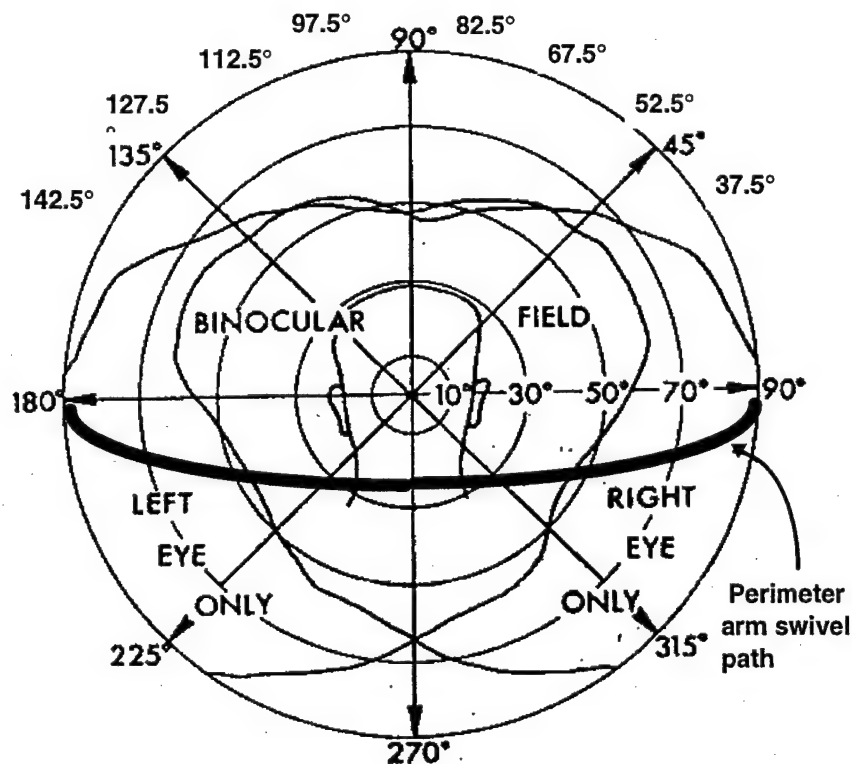


Figure 3. Subject's FOV and the eight lateral visual field positions that were tested.

Eyes

Visual obstructions for both eyes (light bulbs) were measured at the eight lateral visual field positions. During each trial, the FOV of each "eye" was measured separately (the unused "eye" of the headform was unscrewed from its socket). The order of observation between the "eyes" were counter-balanced for each trial.

2.3 Subjects' experimental conditions: Helmets x Position x Eye

Five subjects were used to take measurements of obstructions caused by the helmets, in a within-subjects design study.

Helmets

Only three helmets were compared when human subjects were used. The three helmets were the M1 in-service helmet, the U.S. PASGT, and the British Mk-6. Again, each helmet was worn by each of the subjects in a counter-balanced order.

Position

The same positions within the lateral visual field were measured for obstructions when human subjects were used. This time, the order that the positions were presented was randomized. This was done because humans might be prone to respond by expectation if the order of presentation were not randomized.

Eyes

Visual obstructions for both eyes were measured at the eight lateral visual field positions. The subject's unused eye was covered with an eye patch. The order of presentation to each eye was counter-balanced.

2.4 Subjects

Five subjects, four male and one female between the ages of 25 and 40, participated in this study. Anthropometry measurements were not obtained from the subjects.

2.5 Helmet fitting procedure

A step-by-step guide for fitting a helmet onto a headform or subject's head is attached at Annex B.

2.6 FOV measurement procedure

Using the headform-perimeter, eight separate positions within the lateral visual field were tested for visual obstruction. The rotating arm of the headform-perimeter was swiveled to these eight separate locations within the lateral visual field. At each of the eight positions, the illumination from the headform's light

bulbs (eyes) on the perimeter screen (with or without obstruction from the helmets) was mapped onto specialized paper (Haag Streit Ag Bern-Schweiz form 940-2414). Thus, the vertical visual field limit on extent at each of the test positions were plotted by the experimenter.

The FOV of the subjects was measured by having the subject indicate whether the point of light generated by the perimeter swivel arm was observable, while his/her eyes were fixated to the front.

2.7 Data Analysis

The absolute degrees of FOV (light source unblocked) for each condition were plotted. The degrees of FOV measured from the headform or subject at each of the lateral positions with different helmets were compared to baseline measurements (see Annex D graphs).

Each data set was then transformed to differences in degrees from baseline FOV (FOV measured when not wearing helmet). The differences in degrees from normal FOV were then compared between all the helmets and analyzed using the 3-factor within-subject Analysis of Variance (ANOVA) method. A post-hoc analysis was done to distinguish between the helmets that were significantly different from each other in terms of vertical degrees from normal FOV.

3. RESULTS

3.1 Headform

Results of the ANOVA indicate that the Helmet condition had a significant effect on vertical FOV at the $p = .01$ level where $F(6,71) = 20.43$ (see Figure 4 below). The Fisher LSD post-hoc analysis (Annex C) shows that the British and Israeli brimless helmets were not significantly different from each other and baseline FOV. It shows that the brimmed helmets, including the M-1, Barrday (to a certain extent), PASGT, and Schuberth-Helme covered significantly more visual area than baseline and brimless helmets.

Results of the ANOVA also indicate that the Position condition (the eight chosen locations in the spherical space) had a significant effect on what was seen or not seen, at the $p = .01$ level where $F(5,71) = 6.435$.

The Eye condition (left or right "eye") did not make a significant difference on the FOV measurements, even though the headform's "eyes" were slightly lopsided.

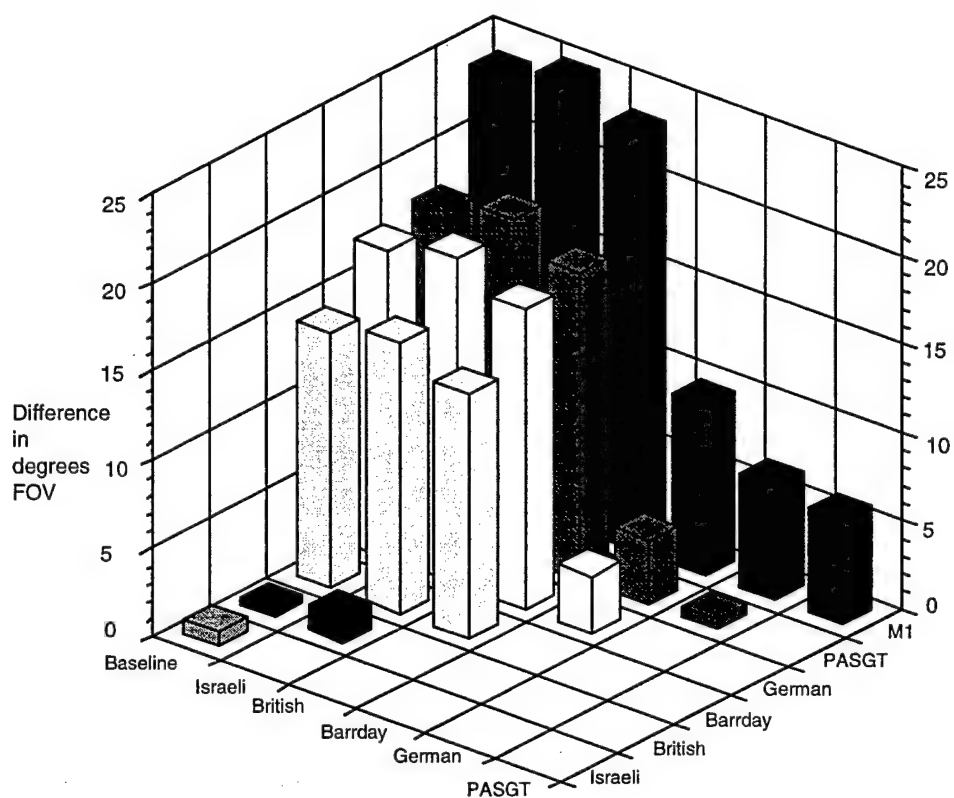


Figure 4. Differences in degrees FOV from baseline for each helmet (headform measurements). The data presented are averaged over three trials for each condition and over the left and right "eyes" of the headform.

3.2 Subjects versus Headform

The results show that FOV reductions for subjects (Figure 5) were similar to headform FOV reductions (Figure 6) for the M1, PASGT, and Mk-6 helmets. The M1 helmet reduced FOV the most compared to the PASGT and the Mk-6. The Mk-6 reduced FOV the least. Although the data set for subject data is incomplete and cannot be compared with headform data for all six helmets, they are consistent with the headform method for the three helmets that were tested.

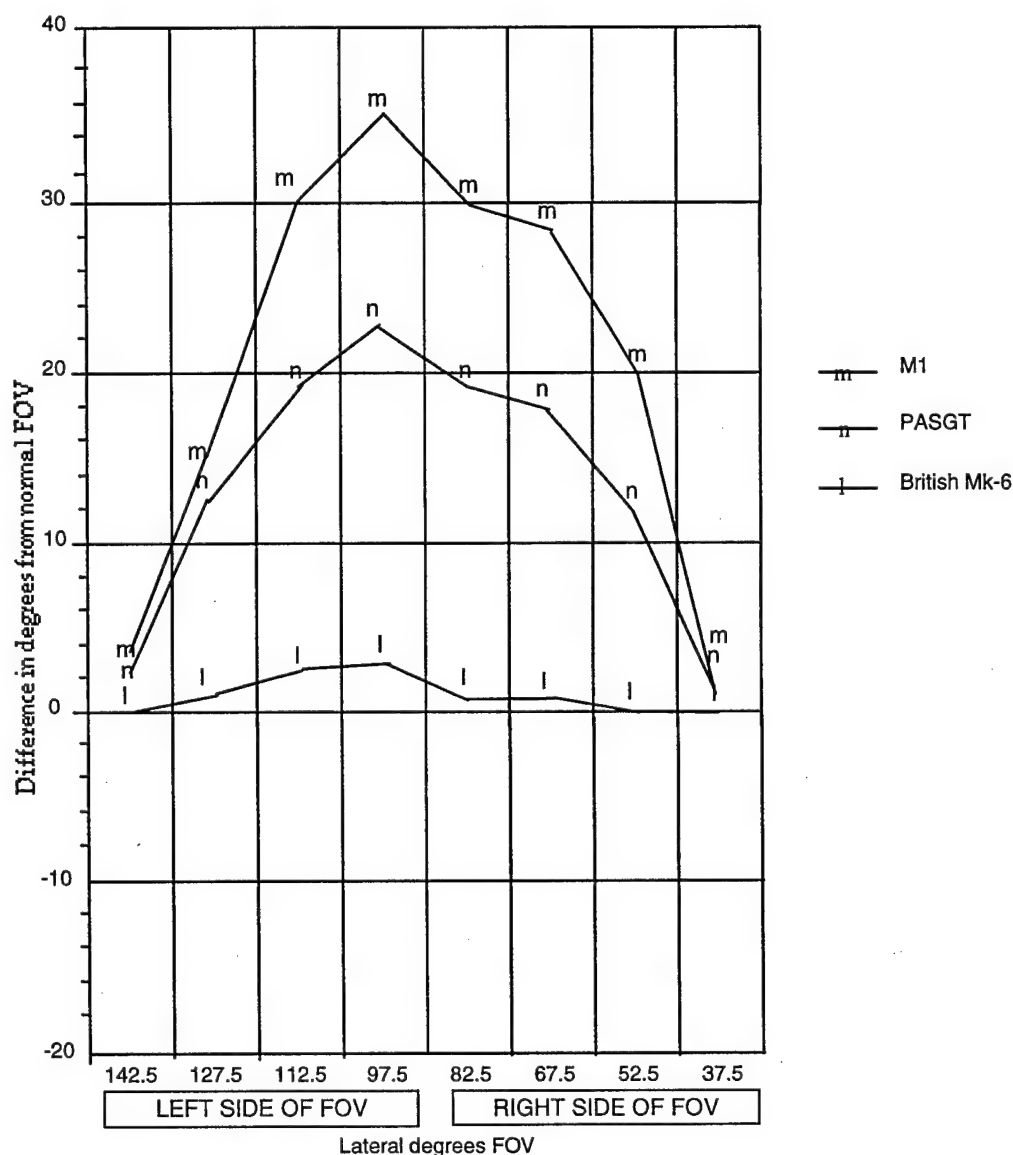


Figure 5. FOV reduction from baseline for three helmets (subjects' results). Measurements were averaged between left and right eyes.

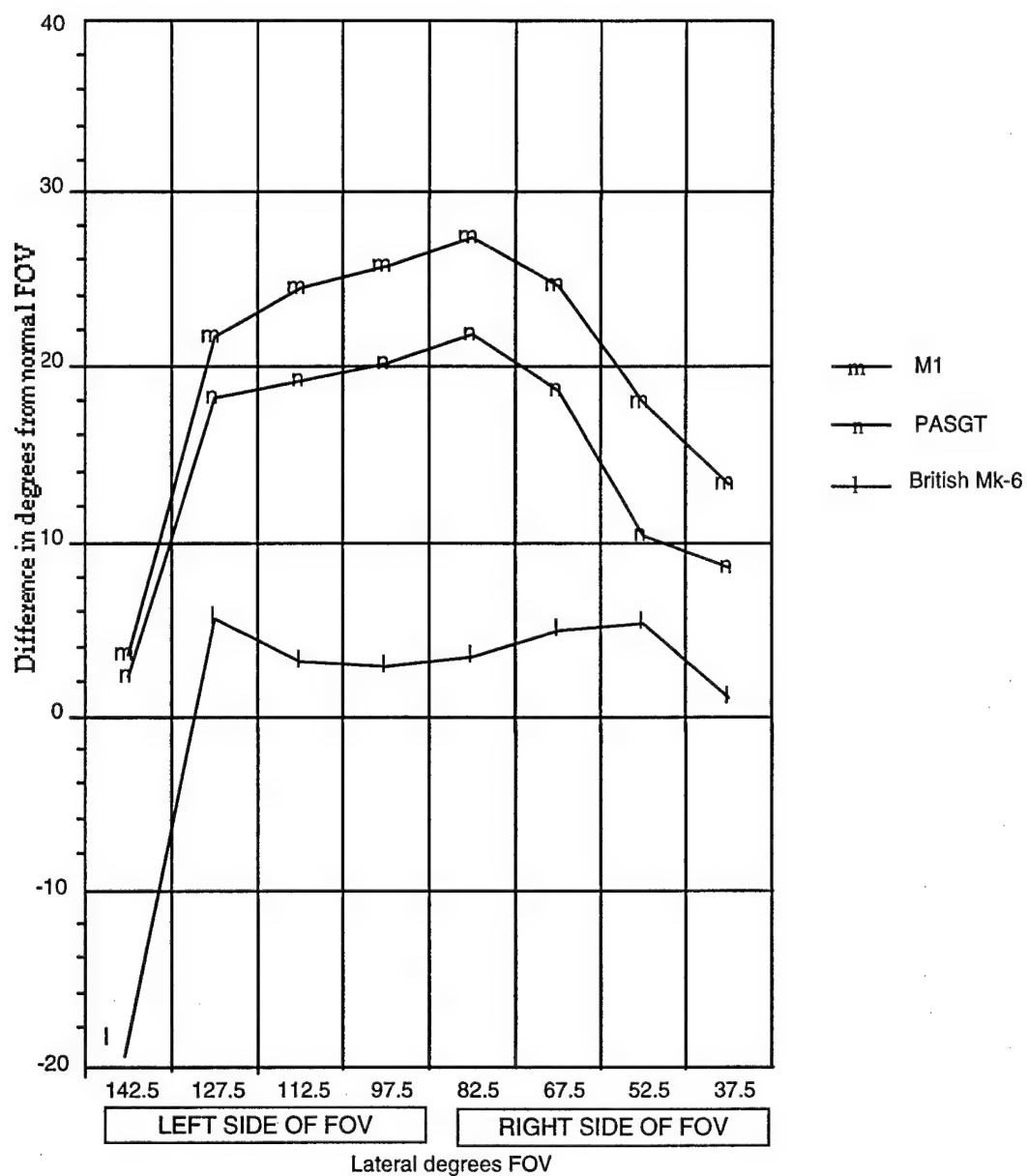


Figure 6. FOV reduction from baseline for three helmets (headform results). Measurements were averaged between left and right "eyes".

The outlier in Figure 6 (first "1" point) may be due to the inconsistency of reading the extent of the light source in the no-helmet condition (see graphs D-5 and D-6, where FOV was greater when the helmets were on the headform than when they were not).

4. DISCUSSION

4.1 *Validity of the headform-perimeter*

Although the absolute FOV measurements between the headform and subjects did not have a 1:1 match, the results distinguished between the brimmed and the brimless helmets. Small discrepancies between Figures 5 and 6 were probably due to experimental error, differences between the subject pool and the headform used, differences between the human eye and the headform's light bulbs, and inadvertent eye movement by the subjects while FOV measurements were taken. Since this method was applicable and sensitive enough, future head-mounted equipment evaluations should include headform FOV measurements.

Since only three of the six helmets were compared between using the headform and human subjects, further validations of the usage of headforms are needed. Future studies should include larger samples using both the headform method and the human subjects method.

4.2 *Standardising the headform's interpupillary distance*

The issue of standardising the headform's interpupillary distance may seem like a trivial matter at first, as measurements are usually compared between baseline and test conditions only. However, a lack of interpupillary distance standardisation is problematic when companies compete to meet human performance specifications. Specifications often state that an item of equipment should not restrict peripheral vision by a specific value, or by a percentage of normal FOV. If the baseline FOV used by one company is larger than that used by others, then the measured restrictions of the FOV are not comparable. The use of a headform or subjects with larger interpupillary distances may result in accepting equipment that causes FOV reduction to an unacceptable extent for most of the user population. Without specifying and standardising the interpupillary distance(s) to use, the measurement would not be a measurement of FOV reduction but a measurement of the interpupillary distance used.

There is controversy as to which standard interpupillary distance(s) to use, when testing for FOV loss due to equipment interference. The anthropometric measure for interpupillary distance for 50th percentile USAF personnel is 63.2 mm³. (The DCIEM headform is a conservative headform, given its relatively small interpupillary distance of 60 millimetres.) The interpupillary distance for the 50th percentile Stoll Head Form (Dutch) is 67 mm¹. It can be argued that the use of a 63.2 mm interpupillary distance is more suitable than using the Stoll headform interpupillary distance since there are no human populations that have a 50th-percentile interpupillary distance as large as 67 mm. However, if 5th and 95th percentile measurements are used, both 60 and 67 mm are acceptable, since the 5th percentile female interpupillary measure is 56.6 mm and the 95th percentile male interpupillary measure is 71.0 mm². What is critical is that the Stoll

interpupillary distance of 67 mm should not be the only distance used in a headform-equipment FOV evaluation. Smaller interpupillary distances such as the DCIEM headform's 60 mm, or more ideally, the 5th percentile female's 56.6 mm interpupillary distance, should also be used. In this way, the critical range of interpupillary distance is covered when testing for FOV reductions. Alternatively, a standardised headform with adjustable interpupillary distances should be used.

4.3 *Standardising eye movement when testing for FOV*

In the medical field, two standard tests are used to measure FOV. The first test measures the visual field with a centrally fixed eye. The second test measures the FOV while allowing the eye to move to its limit and even raising the eyelid if necessary. The two tests use the same luminance conditions, test stimuli, etc.² Both methods are standard and acceptable. The use of one or the other, however, should be specified in any study. At the very least, the evaluator must state which method (fixed or moving eyes) was used in obtaining the measurements.

The results of this study show that FOV measurements made with the subjects fixating their eyes yields similar results to using a headform with fixed eyes. However, if a subject is allowed or instructed to turn the eyes to the temporal regions, 15° is added to the temporal view in each eye. Because 15° is quite a significant difference in FOV measurements, this added temporal FOV alone may account for the variability in maximum FOV measured between researchers⁴. Thus, whether subjects should be allowed to move their eyes is another standardisation issue.

In order to validate the use of a headform for static anthropometry, human subjects must be asked to not move their eyes during the FOV test. If it is established that the headform is a valid measure of static peripheral vision, perhaps the measure of dynamic anthropometry (moving eyes) should be added to the standard FOV test (a headform that has moving eyes may be constructed and validated).

5. CONCLUSIONS

The results of this study showed that: (1) all brimmed helmets caused significant reductions of FOV when compared with baseline measurements (no helmet); (2) brimless helmets (British and Israeli) did not cause any significant reduction of FOV; and (3) the headform FOV measurements were generally consistent with subjects' FOV measurements.

Further validation of this method is needed, by comparing more headform FOV measurements to subjects FOV measurements.

6. RECOMMENDATIONS

6.1 *For project managers*

The following recommendations are geared towards the decision maker or the project manager involved in the CF equipment procurement process:

- a. A brimless or reduced-brim helmet should be considered in future CF purchases;
- b. Future helmet requisitions should be evaluated for visual obstruction in a similar manner before procurement; and
- c. When standardised, a similar test method should be used in the future to define Statements of Requirement, performance specifications, and other related documents.

6.2 *For researchers*

The following recommendations are geared towards the researcher or the evaluators involved in the CF equipment procurement process:

- a. More studies should be done to validate the usage of a headform-perimeter for helmet- and other head-mounted equipment compatibility testing;
- b. Headform dimensions and interpupillary distances need to be standardised; and
- c. Using fixated or moving eyes during the FOV tests should be standardised.

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ANNEX A

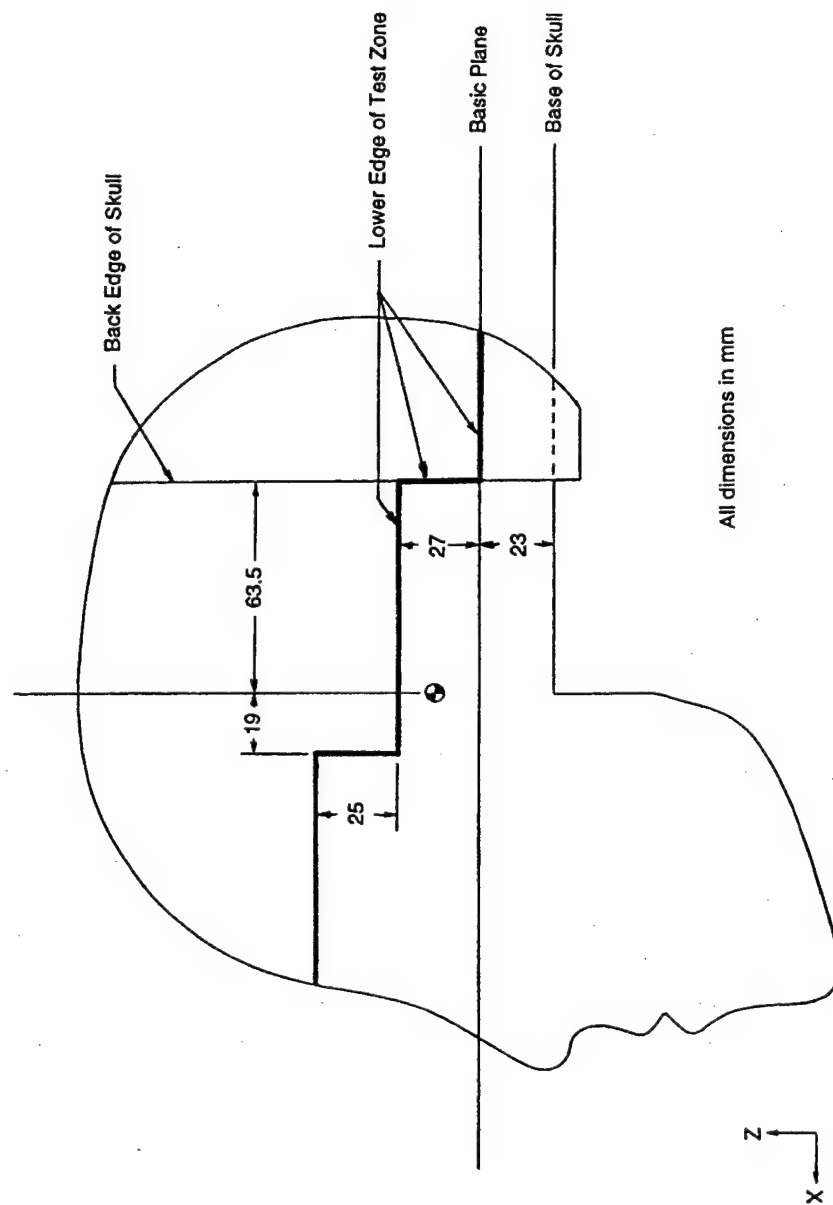


Figure A-1. Test headform used for Field of View testing.

ANNEX B

Helmet Fitting Procedure

Helmet positioning and ability to achieve repeatable positions of the helmet are important in order to reduce the effects of experimental error. The following is a guide for fitting helmets onto headforms. The same care should be taken when fitting helmets onto human subjects.

1. Mark a reference point on the middle of the lower back of the headform/subject's head corresponding to the positioning index. This will be used to ensure proper fore and aft alignment of the helmet.
2. Select two identical reference points on each side of the helmet. The helmet headband or reference dimples on the shell may be used.
3. Loosen all harness straps and nape straps. Follow the manufacturer's instructions as necessary.
4. Place the helmet on the headform or subject's head.
5. Press down on the front, back and top of the helmet applying a sufficient load to eliminate gapping between the headform/head and the suspension system.
6. Rotate the helmet such that the back centre of the helmet and the mark on the back of the headform/head line-up. This is achieved by holding a ruler horizontally at the positioning mark on the headform/head and rotating the helmet until the first contact with the ruler is made.
7. Align the helmet such that it is positioned symmetrically with respect to the X-Z plane of the headform/head by visual inspection.
8. Secure the chin strap and apply a tension tangentially to the chin strap. Brace the helmet shell at the strap mounting location to minimize movement of the helmet. If the nape strap is independent of the chin strap, secure it by applying a similar tension.
9. Confirm helmet alignment.
10. It is necessary to check the alignment of the eyes and helmet before each measurement. Measure Left and Right eyes' FOV, but only for the top 180° as this is the area of interest for the helmet study.

ANNEX C

Table of post-hoc analysis of factor "Helmet

NB: A pairwise comparison of levels of significance for differences in degrees obstruction.

Fisher's Protected LSD
Effect: Helmet
Dependent: Degrees
Significance level: .05

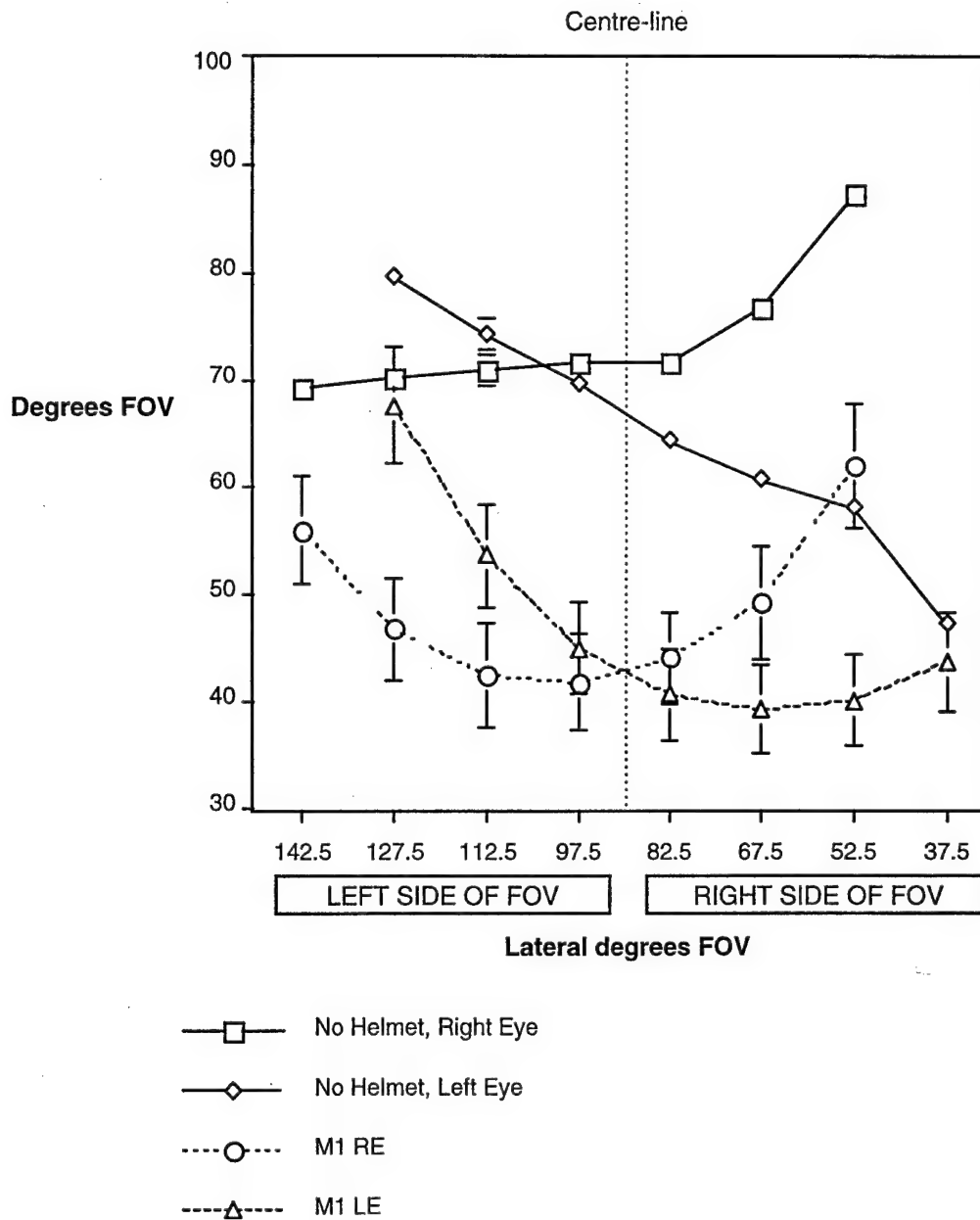
	Vs.	Diff.	Crit. diff.	P-Value	
M1	PASGT	5.917	6.438	.0711	
	German	6.375	6.438	.0522	
	Barrday	9.533	6.438	.0043	S
	British	23.350	6.438	.0001	S
	Baseline	23.883	6.438	.0001	S
	Israeli	24.808	6.438	.0001	S
PASGT	German	.458	6.438	.8875	
	Barrday	3.617	6.438	.2664	
	British	17.433	6.438	.0001	S
	Baseline	17.967	6.438	.0001	S
	Israeli	18.892	6.438	.0001	S
German	Barrday	3.158	6.438	.3313	
	British	16.975	6.438	.0001	S
	Baseline	17.508	6.438	.0001	S
	Israeli	18.433	6.438	.0001	S
Barrday	British	13.817	6.438	.0001	S
	Baseline	14.350	6.438	.0001	S
	Israeli	15.275	6.438	.0001	S
British	Baseline	.533	6.438	.8693	
	Israeli	1.458	6.438	.6529	
Baseline	Israeli	.925	6.438	.7753	

S = Significantly different at this level.

ANNEX D

Figure D-1. Plot of Baseline and M1 FOVs

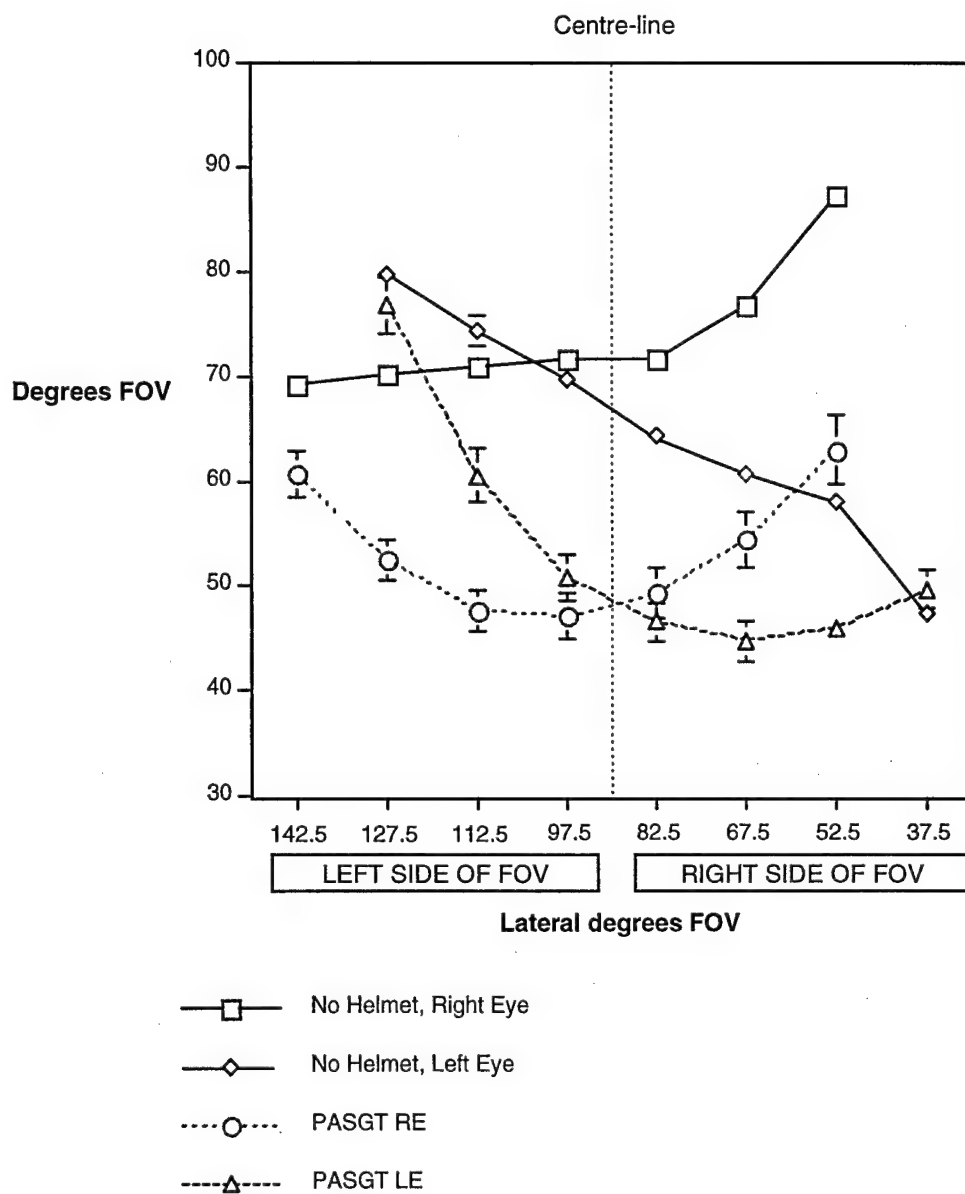
NB: Left and right eye field of view in degrees seen



ANNEX D

Figure D-2. Plot of Baseline and PASGT FOVs

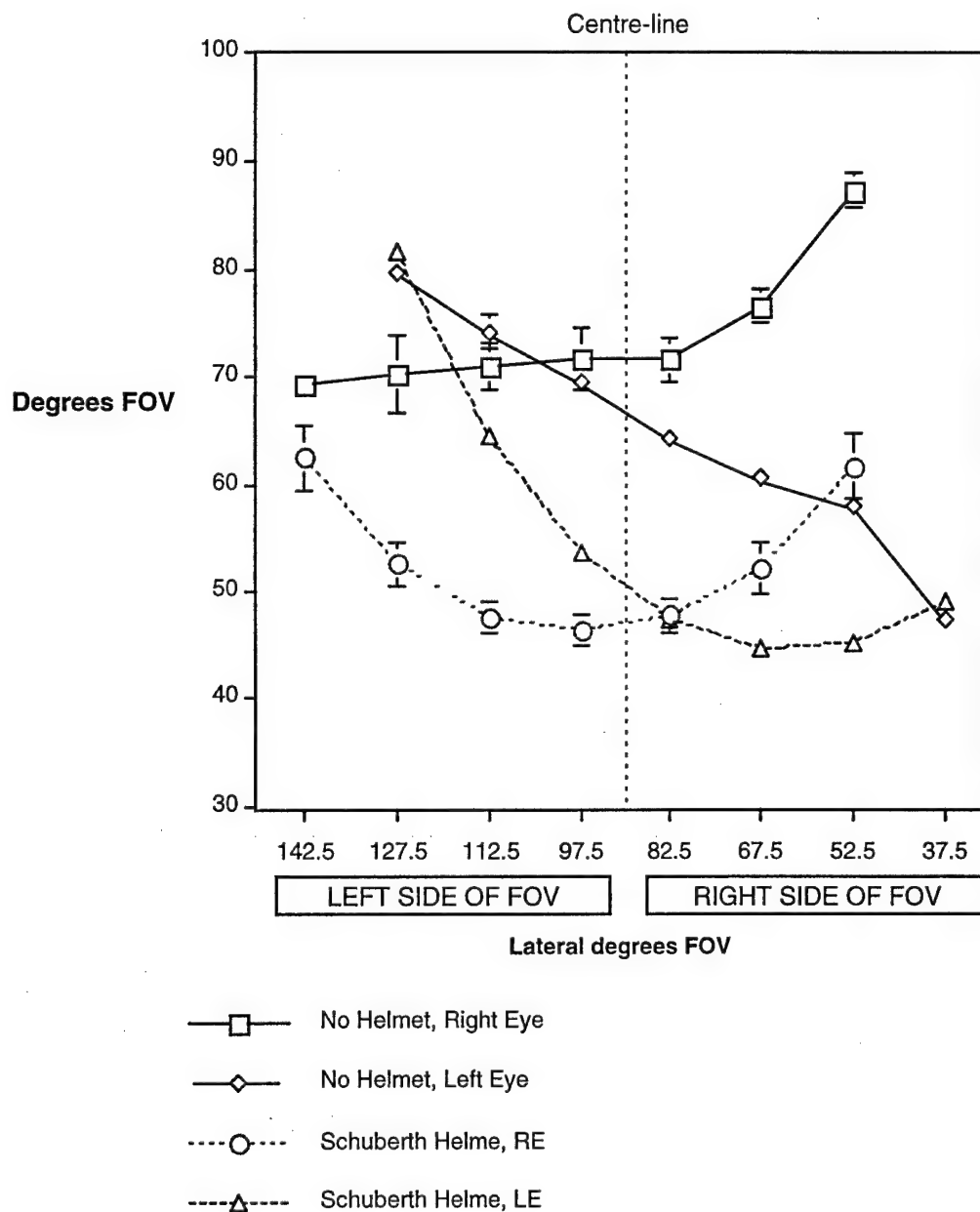
NB: Left and right eye field of view in degrees seen



ANNEX D

Figure D-3. Plot of Baseline and Schuberth Helme FOVs

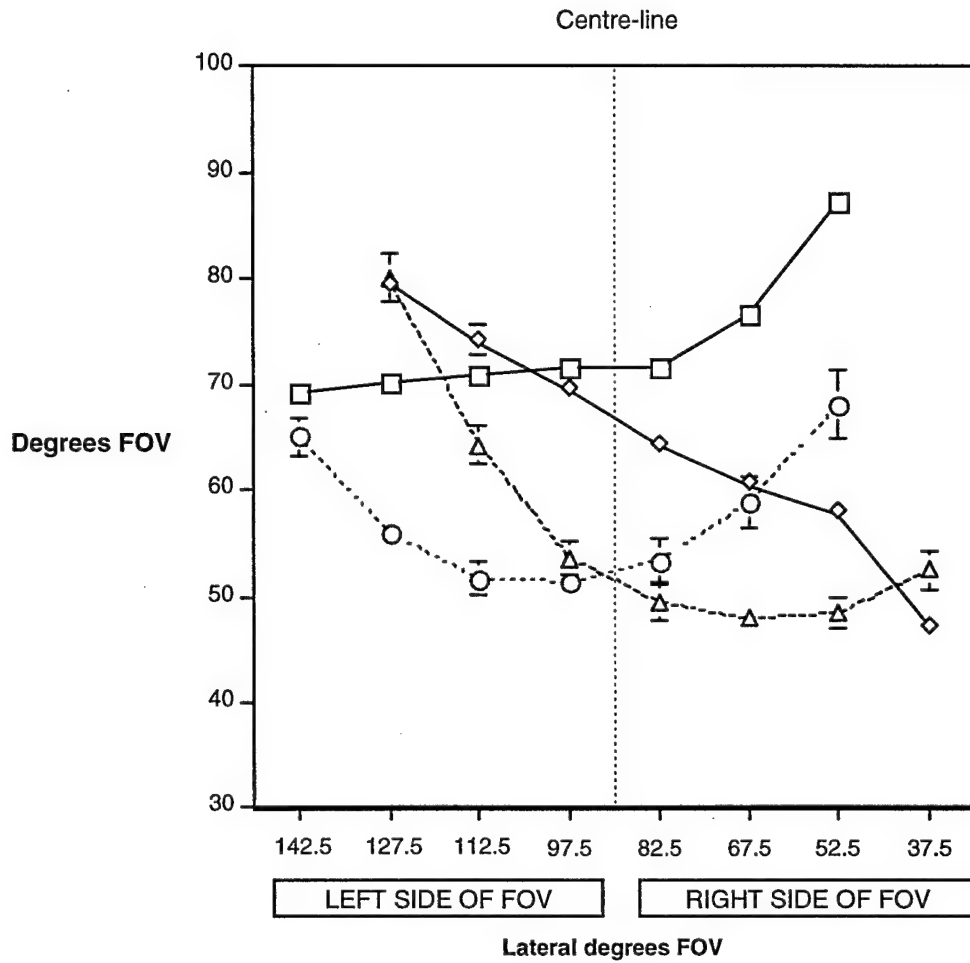
NB: Left and right eye field of view in degrees seen



ANNEX D

Figure D-4. Plot of Baseline and Barrday FOVs

NB: Left and right eye field of view in degrees seen

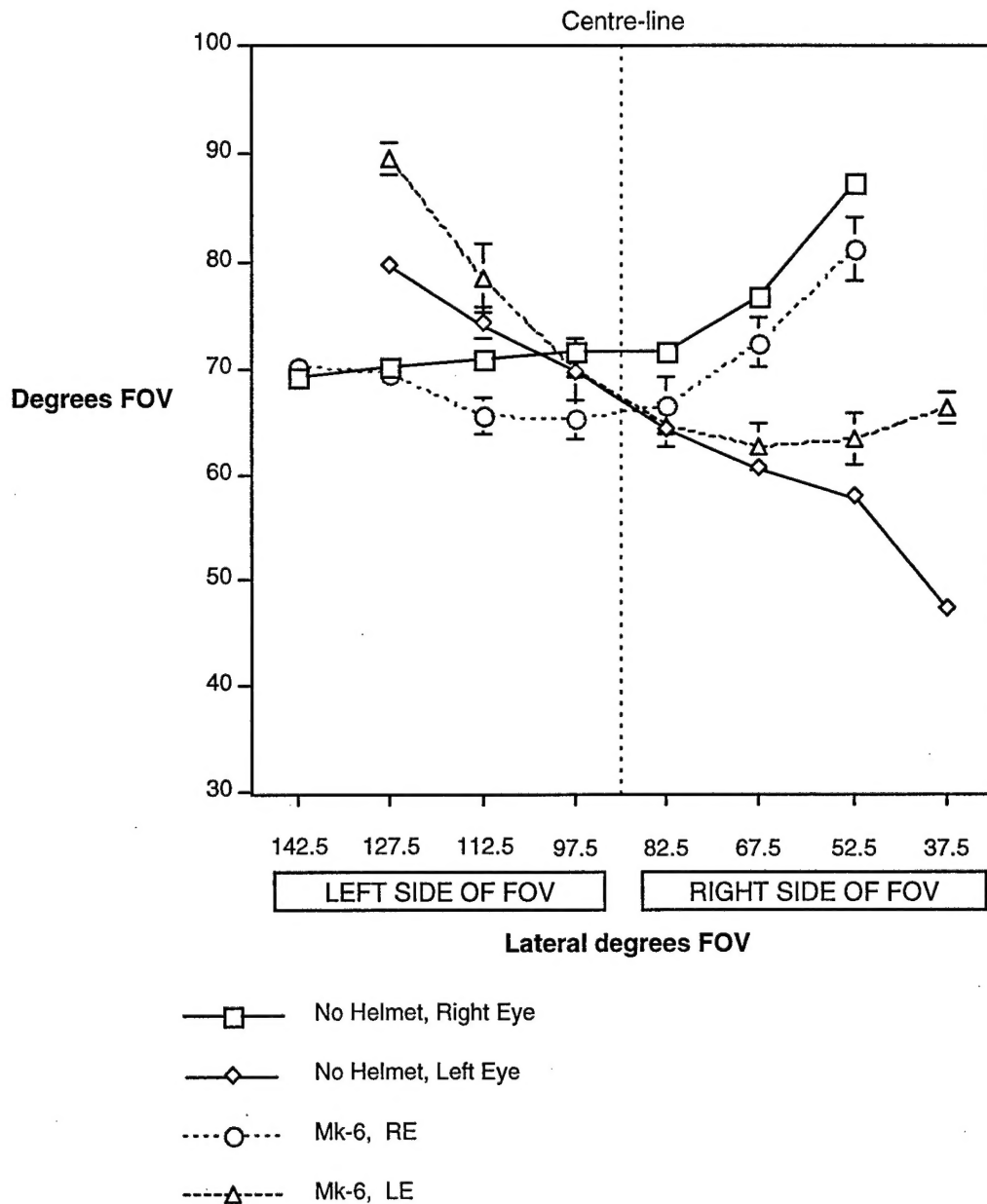


- No Helmet, Right Eye
- ◇— No Helmet, Left Eye
- Barrday RE
- △--- Barrday LE

ANNEX D

Figure D-5. Plot of Baseline and Mk-6 FOVs

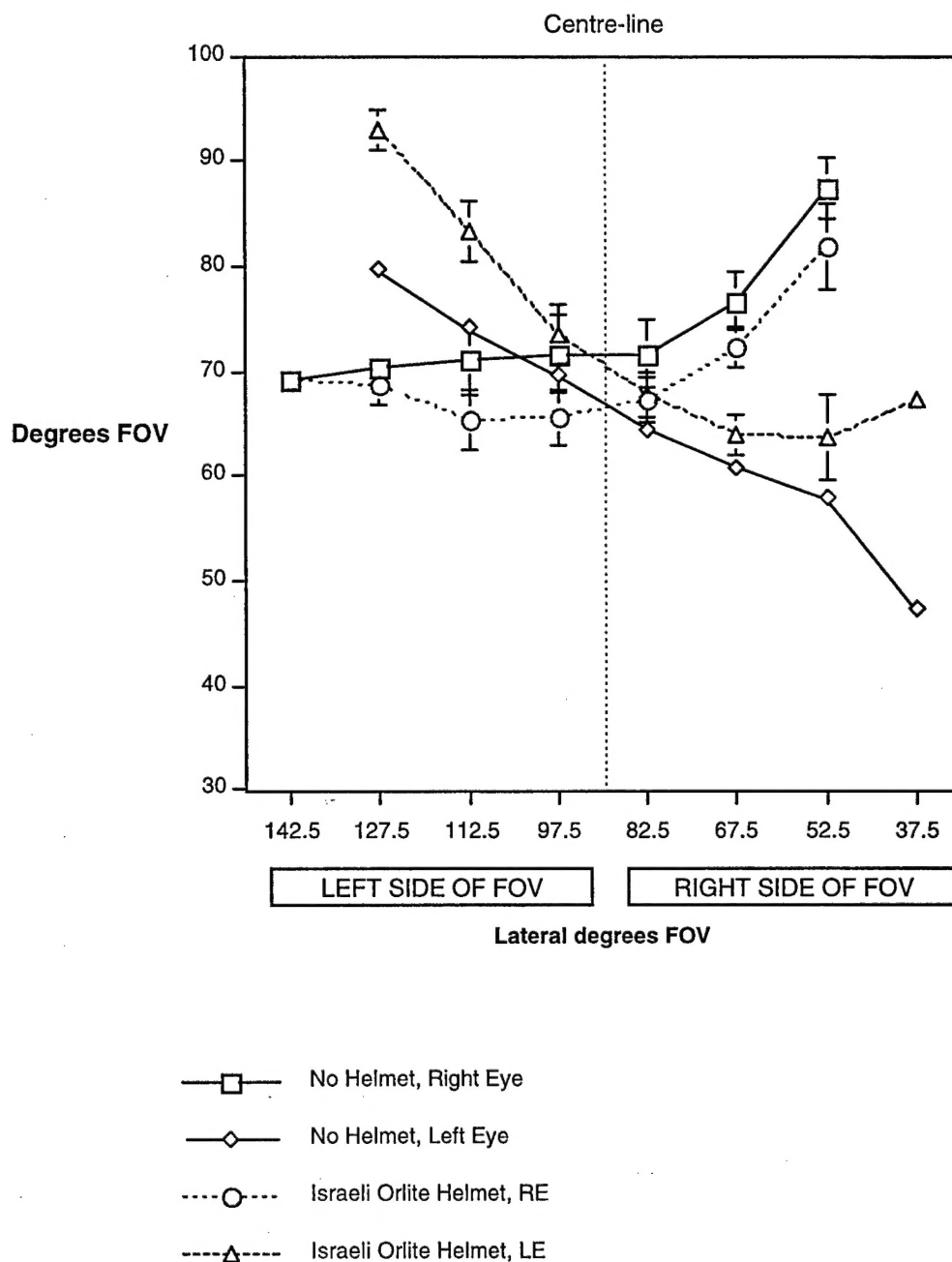
NB: Left and right eye field of view in degrees seen



ANNEX D

Figure D-6. Plot of Baseline and Israeli Orlite FOVs

NB: Left and right eye field of view in degrees seen



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An evaluation of contender helmets for visual obstruction and preliminary validation of a visual obstruction measuring tool

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The aim of this study was to (1) use a headform-perimeter to evaluate contender army helmets for visual interference; and (2) determine the effectiveness and validity of using the headform-perimeter to measure visual interference compared to using human subjects. A headform was made in-house to be used with a standard Goldmann perimeter. The headform-perimeter was used to evaluate the six contender helmet for visual obstructions, by measuring loss of field of view (FOV). In a separate study, human subjects FOV measurements were obtained with the same Goldmann perimeter. Subjects' loss of FOV while wearing various helmets were measured. The results showed that: (1) all brimmed helmets caused significant reductions of FOV when compared with baseline measurements (no helmet); (2) brimless helmets (British and Israeli) did not cause any significant reduction of FOV; and (3) the headform FOV data were consistent with subjects' FOV measurements, for three of the six test helmets.

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Field of view (FOV)

Goldmann perimeter

headform

helmets

visual obstruction

interference

incompatibility

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